NAVAL POSTGRADUATE SCHOOL
Monterey, California

THESIS

FACULTY FORECAST AND PLANNING MODEL FOR THE NAVAL POSTGRADUATE SCHOOL

by

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March 1997

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REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY (Leave Blank)

2. REPORT DATE
March 1997

3. REPORT TYPE AND DATES COVERED
Master's Thesis

4. TITLE AND SUBTITLE
FACULTY FORECAST AND PLANNING MODEL FOR THE NAVAL POSTGRADUATE SCHOOL

5. FUNDING NUMBERS

6. AUTHOR(S)
Shipman, Brian K.

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Naval Postgraduate School
Monterey, CA 93943-5000

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSORING / MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES
The views expressed in this thesis are those of the author and do not reflect the official policy or position of the Department of Defense or the U.S. Government.

12a. DISTRIBUTION / AVAILABILITY STATEMENT
Approved for public release, distribution is unlimited

12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)

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The model estimates faculty retention characteristics, or continuation rates based upon the length of federal service (LFS) associated with historic loss data. These continuation rates are applied to a cross-sectional faculty profile to predict faculty legacies, i.e. the number of faculty who will continue service at NPS. Results show that faculty levels can be predicted with relative certainty out to a two year horizon. Additionally, the results show how salary increases in the early 1990's induced a delay in faculty retirements.

We also present an embellishment to the model which incorporates age at loss as well as LFS to forecast only retirements. The forecasts from this model are not as conclusive as those obtained from the original.

14. SUBJECT TERMS
Forecasting, Manpower Modeling, Faculty Planning, Renewal Process, Operations Research

15. NUMBER OF PAGES
48

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	UL

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. 239-18
298-102

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FACULTY FORECAST AND PLANNING MODEL FOR THE NAVAL POSTGRADUATE SCHOOL

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Submitted in partial fulfillment
of the requirements for the degree of

MASTER OF SCIENCE IN OPERATIONS RESEARCH

from the

NAVAL POSTGRADUATE SCHOOL
March 1997

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ABSTRACT

This thesis develops a model for the Naval Postgraduate School (NPS) to forecast future tenure-track faculty size and distribution. It enables decision makers to analyze the effects of tenure and retirement policies as well as determine recruitment levels to achieve and maintain a desired number of faculty members.

The model estimates faculty retention characteristics, or continuation rates based upon the length of federal service (LFS) associated with historic loss data. These continuation rates are applied to a cross-sectional faculty profile to predict faculty legacies, i.e. the number of faculty who will continue service at NPS. Results show that faculty levels can be predicted with relative certainty out to a two year horizon. Additionally, the results show how salary increases in the early 1990's induced a delay in faculty retirements.

We also present an embellishment to the model which incorporates age at loss as well as LFS to forecast only retirements. The forecasts from this model are not as conclusive as those obtained from the original.

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EXECUTIVE SUMMARY

Recent budget cuts have forced all military activities, including the Naval Postgraduate School (NPS) to operate more efficiently. Tightened budgets require better planning to continue operations. One of the major budget items for NPS is faculty salaries. To better predict and plan future salary outlays and recruitment policies, a model for forecasting future tenure-track faculty size and distribution is needed.

Achieving and maintaining a specific level of faculty members requires an understanding of faculty retention characteristics. If the rate at which faculty members leave NPS can be ascertained and predicted with some certainty, then recruitment levels can be set to maintain a more steady-state faculty base. Insights into this retention behavior can be obtained from historic loss data.

Three specific time elements are associated with a faculty loss: the person's age at loss, length of federal service (LFS) and years of service at NPS (YNPS). Considering that retirement eligibility and pension annuities are based upon total federal service time, LFS seems to be the most appropriate base for forecasting. Age also influences retirement options, but it does not intuitively seem to be a reliable indicator of retention behavior since new faculty are hired over a wide range of ages.

This thesis develops a model to forecast future faculty size and distribution. The model estimates retention characteristics or *continuation rates* based upon LFS, but the structure of the model allows for any of the three elements mentioned above to be used. These continuation rates are applied to a current cross-sectional faculty profile to predict faculty legacies, i.e. the number of faculty who will continue service at NPS. From these legacies decision makers are able to analyze the effects of tenure and retirement policies as well as determine recruitment levels to achieve and maintain a desired number of faculty members.

Results show that faculty levels can be predicted with relative certainty out to a two year horizon. Additionally, the results show how salary increases in the early 1990's have apparently induced a recent delay in faculty retirements.

We also present an embellishment to the model which incorporates two elements of the loss data, age at loss and LFS to forecast only retirements. Although the approach seems intuitively applicable to retirement forecasts, the results from this model are not as conclusive as those obtained from the original, in part because of insufficient historic data.

The models developed in this thesis are programmed into Excel spreadsheets.

ACKNOWLEDGEMENTS

I would like to express my deepest appreciation to Professor Kneale T. Marshall. His insight, professionalism and patience were instrumental to this research effort.

Most importantly, I extend my sincerest gratitude to my wife and family for their untiring support, devotion and sacrifice throughout my career.

I. INTRODUCTION

Recent budget cuts have forced all military activities, including the Naval Postgraduate School (NPS) to "do more with less". Tightened budgets require better planning to continue operations. One of the major budget items for NPS is faculty salaries. To better predict and plan future salary outlays and recruitment policies, a model for forecasting future faculty size and distribution is needed.

Achieving and maintaining a specific level of faculty members requires knowledge of faculty retention behavior. If the rate at which faculty members leave NPS can be ascertained and predicted with some certainty, then recruitment levels can be set to maintain a more steady-state faculty base. Insights into this retention behavior can be derived from historic loss data.

Three specific time elements are associated with a faculty loss: the person's age at loss, length of federal service (LFS) and years of service at NPS (YNPS). Since NPS service time is federal employment, LFS and YNPS are the same for most faculty members. Exceptions exist when a faculty member has previous federal service such as active duty before joining NPS. However, considering that retirement eligibility and pensions are based upon total federal service time, LFS seems to be more appropriate as a base for forecasting. Age also influences retirement options, but it does not intuitively seem to be a reliable indicator of retention behavior since new faculty are hired over a wide range of ages. The model presented in this thesis estimates retention or *continuation*

characteristics based upon LFS, but the structure of the model allows for any of the three elements to be used. Historic data on all three elements are found in Appendix A.

This thesis develops a model to forecast faculty size and distribution based upon LFS. Chapter II discusses model assumptions, conventions and development. The model is tested in Chapter III, where loss data from FY87 through FY93 are used to estimate model parameter values. These values are then used to predict faculty size and composition for FY94, FY95 and FY96 and the results compared with actual observations. In Chapter IV we discuss an embellishment of the model for predicting only faculty retirements, rather than all faculty losses. In Chapter V we present conclusions and recommendations.

II. MODEL DEVELOPMENT

This chapter first discusses the conventions and assumptions necessary for the forecasting model, then develops the legacy (defined below) forecasting equations. Finally, the cumulative distribution function (CDF) for an arbitrary faculty member's length of federal service is estimated using historic loss data.

A. TIME CONVENTION

As a convention throughout this thesis, a year t is defined in terms of a government fiscal year (FY) that begins on October 1st of year t-1 and runs through September 30th of year t. Cross-sectional profiles of faculty levels are referenced from the *end* of FY t just before the beginning of FY t+1.

B. LEGACY FORECASTING EQUATIONS

At $t = 0$, let the number of faculty members at NPS be n, indexed $i = 1, 2, \ldots, n$, with LFS = l_i, where l_i is discretized using the ceiling function. For example, if a faculty member with no prior federal service is hired at any point in FY88, say on 1 October 1987 or any day up to and including 30 September 1988, then $l_i = 1$ for that faculty member at the end of FY88. Similarly, if a faculty member has LFS l_i at t, then LFS at the end of any year t' ($> t$) is $l_i + (t' - t)$.

Suppose the year counting system is indexed zero at the end of some fiscal year of interest. Let $N(t)$ be the total number of faculty members still present at time t of those

that were present at time zero. $N(t)$ is called the faculty *legacy* from time zero. We define $Y_i(t)$ as a Bernoulli random variable for an individual faculty member (legacy) i, where

$$Y_i(t) = \begin{cases} 1 & \text{if faculty member } i \text{ is present at time } t, \\ 0 & \text{otherwise.} \end{cases}$$

The total legacy of faculty members present at time t is

$$N(t) = \sum_{i=1}^{n} Y_i(t), \qquad \text{such that}$$

$$E[N(t)] = \sum_{i=1}^{n} E[Y_i(t)]. \tag{1}$$

Additionally, if we assume that individual faculty losses occur independently, then

$$Var[N(t)] = \sum_{i=1}^{n} Var[Y_i(t)]. \tag{2}$$

Equations (1) and (2) are the *Legacy Forecasting Equations* of the model.

Let $\boldsymbol{L_i}$ be the random variable that represents the LFS for faculty member i (i.e. the total number of years i spends in federal service). We employ conditional expectation to determine $E[Y_i(t)]$ and $Var[Y_i(t)]$. Recall that at $t = 0$ faculty member i has a LFS equal to l_i. By definition $Y_i(t)$ is equal to one if and only if $\boldsymbol{L_i}$ exceeds l_i. Conditioning on l_i, we get

$$\begin{aligned} E[Y_i(t)] &= 1 \times P\{\boldsymbol{L_i} \geq l_i + t \mid \boldsymbol{L_i} \geq l_i\} \\ &= \frac{P\{\boldsymbol{L_i} \geq l_i + t, \boldsymbol{L_i} \geq l_i\}}{P\{\boldsymbol{L_i} \geq l_i\}} \\ &= \frac{P\{\boldsymbol{L_i} \geq l_i + t\}}{P\{\boldsymbol{L_i} \geq l_i\}}. \end{aligned} \tag{3}$$

Additionally, since $Y_i(t)$ is a Bernoulli trial,

$$Var[Y_i(t)] = E[Y_i(t)][1 - E[Y_i(t)]]. \tag{4}$$

C. CONTINUATION RATES

We now define a one year continuation rate $c(x)$ as the probability that a faculty member with x years of service will continue service one or more years. That is,

$$c(x) = P\{\boldsymbol{L_i} \geq x+1 | \boldsymbol{L_i} \geq x\} = \frac{P\{\boldsymbol{L_i} \geq x+1\}}{P\{\boldsymbol{L_i} \geq x\}}, \tag{5}$$

which is analogous to the result in Equation (3) when $t = 1$. By substituting $c(x)$ into Equation (3), we get

$$E[Y_i(t)] = \prod_{j=0}^{t-1} c(l_i + j). \tag{6}$$

To demonstrate this form of the equation, let us find the probability that a current faculty member i (one who is present at time zero) will continue service at NPS for an additional three years. Using Equation (6) followed by Equation (5),

$$E[Y_i(3)] = \prod_{j=0}^{2} c(l_i + j) = c(l_i)c(l_i + 1)c(l_i + 2)$$

$$= \frac{P\{\boldsymbol{L_i} \geq l_i + 1\}}{P\{\boldsymbol{L_i} \geq l_i\}} \bullet \frac{P\{\boldsymbol{L_i} \geq l_i + 2\}}{P\{\boldsymbol{L_i} \geq l_i + 1\}} \bullet \frac{P\{\boldsymbol{L_i} \geq l_i + 3\}}{P\{\boldsymbol{L_i} \geq l_i + 2\}}$$

$$= \frac{P\{\boldsymbol{L_i} \geq l_i + 3\}}{P\{\boldsymbol{L_i} \geq l_i\}},$$

which agrees with Equation (3).

By using the result in Equation (6), the *Legacy Forecasting Equations* now become

$$E[N(t)] = \sum_{i=1}^{n} \prod_{j=0}^{t-1} c(l_i + j), \tag{7}$$

$$Var[N(t)] = \sum_{i=1}^{n} \left[\prod_{j=0}^{t-1} c(l_i - j) \right] \left[1 - \prod_{j=0}^{t-1} c(l_i - j) \right]. \tag{8}$$

D. ESTIMATING THE DISTRIBUTION OF L_i

1. Methodology

Equations (5) and (7) together show that in order to forecast faculty legacies the distribution of L_i (i.e. the time that a faculty member spends in federal service) is needed. One method to estimate this distribution is the use of longitudinal manpower models that describe the flow of a particular faculty group, or cohort, through their tenure at NPS. These longitudinal models incorporate realistic personnel flows, but extensive data are required which are not always available [Marshall, 1977]; it is not practical to observe a cohort of new faculty over their time spent in federal service since this could take as long as forty years.

Instead of cohort data, this thesis uses faculty losses modeled as a renewal process to estimate the underlying distribution. A total of 133 faculty losses occurred at NPS from FY87 to FY96. When a loss occurs it signifies the end of a realization of the random variable L [Ross, 1993]. Thus, the losses give us 133 realizations of L from which its probability distribution can be estimated. See Appendix A for the full set of loss data.

2. Loss Data

Figure 2.1 shows the faculty losses as compared to the length of federal service at loss. Losses were caused by retirement, resignation, non-reappointment or death. From

the plot in Figure 2.1, losses appear to fall in one of four groups based upon the length of federal service. The first group of losses occurs when the length of service is 10 years or less. These are due primarily to tenure and non-reappointment decisions. The second group, with 10-23 years of service, consists mainly of mid-career resignations where faculty members accept other teaching positions or transition to other employment. The third loss group extends from 24-32 years of service, where faculty members retire immediately upon, or soon after becoming retirement eligible. The final loss group, those with 35 or more years of service, round out the retirees.

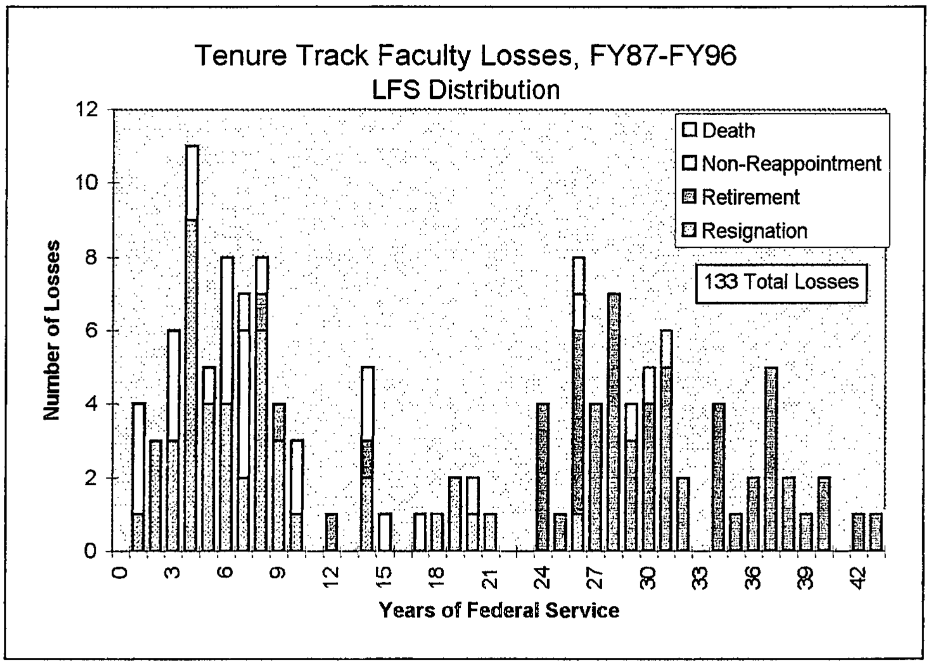

Figure 2.1. Faculty losses versus years of federal service.

3. Estimation

Table 2.1 shows the loss data in tabular form. In the first column, x is the length of federal service in years. Column two contains the number of losses with LFS equal to x at

the time of loss. Column three is the probability mass function, or the number of losses equal to x divided by the total losses. The cumulative tail distribution, or the probability that LFS exceeds x is in column four. The values in column four lead directly to the continuation rates $c(x)$ in column five as determined using Equation (5).

Returning to the example in section C to illustrate the use of Table 2.1, let us assume that at $t = 0$ a faculty member i has just completed six years of federal service, i.e. l_i □ 6. The probability that faculty member i continues service at least three more years is $c(6)c(7)c(8) = .7789$ using Equation (6).

The sum of the cumulative tail probabilities appears at the bottom of column four. This value (18.1) is an estimate of the mean of $\boldsymbol{L_i}$, the average length of federal service for a faculty member in this loss group.

E. HIRING POLICIES

The model enables a decision maker to determine the steady-state number of faculty recruits per year that will achieve and maintain a desired number of faculty members, assuming that the distribution of $\boldsymbol{L_i}$ does not change significantly over time. With this steady-state assumption, the number of recruits per year, λ, is determined by dividing the desired faculty size, $\boldsymbol{N}$, by $E[\boldsymbol{L_i}]$. That is,

$$\lambda = \frac{\boldsymbol{N}}{E[\boldsymbol{L_i}]} \tag{9}$$

x	#LFS=x	P{LFS=x}	P{LFS>x}	$c(x)$
0	0	0	1.0	**1.0**
1	4	0.0301	0.9699	**0.9699**
2	3	0.0226	0.9474	**0.9767**
3	6	0.0451	0.9023	**0.9524**
4	11	0.0827	0.8195	**0.9083**
5	5	0.0376	0.7820	**0.9541**
6	8	0.0602	0.7218	**0.9231**
7	7	0.0526	0.6692	**0.9271**
8	8	0.0602	0.6090	**0.9101**
9	4	0.0301	0.5789	**0.9506**
10	3	0.0226	0.5564	**0.9610**
11	0	0.0000	0.5564	**1.0000**
12	1	0.0075	0.5489	**0.9865**
13	0	0.0000	0.5489	**1.0000**
14	5	0.0376	0.5113	**0.9315**
15	1	0.0075	0.5038	**0.9853**
16	0	0.0000	0.5038	**1.0000**
17	1	0.0075	0.4962	**0.9851**
18	1	0.0075	0.4887	**0.9848**
19	2	0.0150	0.4737	**0.9692**
20	2	0.0150	0.4586	**0.9683**
21	1	0.0075	0.4511	**0.9836**
22	0	0.0000	0.4511	**1.0000**
23	0	0.0000	0.4511	**1.0000**
24	4	0.0301	0.4211	**0.9333**
25	1	0.0075	0.4135	**0.9821**
26	8	0.0602	0.3534	**0.8545**
27	4	0.0301	0.3233	**0.9149**
28	7	0.0526	0.2707	**0.8372**
29	4	0.0301	0.2406	**0.8889**
30	5	0.0376	0.2030	**0.8438**
31	6	0.0451	0.1579	**0.7778**
32	2	0.0150	0.1429	**0.9048**
33	0	0.0000	0.1429	**1.0000**
34	4	0.0301	0.1128	**0.7895**
35	1	0.0075	0.1053	**0.9333**
36	2	0.0150	0.0902	**0.8571**
37	5	0.0376	0.0526	**0.5833**
38	2	0.0150	0.0376	**0.7143**
39	1	0.0075	0.0301	**0.8000**
40	2	0.0150	0.0150	**0.5000**
41	0	0.0000	0.0150	**1.0000**
42	1	0.0075	0.0075	**0.5000**
43	1	0.0075	0.0000	**0.0000**
TOTAL	133	1.0	18.135	

Table 2.1. Loss distribution and continuation rate calculations.

III. MODEL TESTING

In this chapter we use a subset of the loss data (FY87 through FY93) to generate continuation rates. These rates are used to forecast faculty legacies from the FY93 faculty cross section. The forecasts are then compared against the actual legacies to assess the model's performance. All calculations are performed using Microsoft Excel (Microsoft Corporation, 1995).

A. THE DEMONSTRATION DATA

A total of 104 faculty losses occurred at NPS from 1 October 1986 to 30 September 1993. These realizations of $\boldsymbol{L}$ are used to estimate the underlying distribution and calculate continuation rates as discussed in Chapter II. Loss distribution and continuation rate calculations are contained in Figure B.1 and Table B.1, Appendix B.

B. HOMOGENEITY OF THE LOSS DISTRIBUTION

The model requires no assumptions about the exact distribution of faculty losses, but the approach taken to test the model assumes *homogeneity* of the loss distribution across time. If faculty losses are not homogenous over time, then faculty loss tendencies have changed and the continuation rates calculated from the subset of the data may not reflect future loss behavior well enough to provide accurate forecasts.

To investigate the homogeneity of the data, we first compare the two estimates of $E[\boldsymbol{L}_i]$. From the Table B.1, the expected value of $\boldsymbol{L}_i$ for the subset of loss data is 17.85 versus 18.14 calculated for the entire set of losses. This suggests that faculty are

remaining in service longer after FY93. Figure 3.1 compares the cumulative tail distributions of the loss data. For LFS in the range 0-10, the two curves coincide. This indicates that tenure and reappointment policies have remained constant from year to year. The small differences that occur for LFS in the range of 11-20 indicate that there is no change in the fraction of mid-career resignations from year to year. There is, however a significant difference in the two curves for LFS greater than 20, namely the retirement eligible group. One implication from this plot is that forecasts for FY94 and beyond will tend to *underestimate* the number of legacies for faculty members with $l_i > 20$.

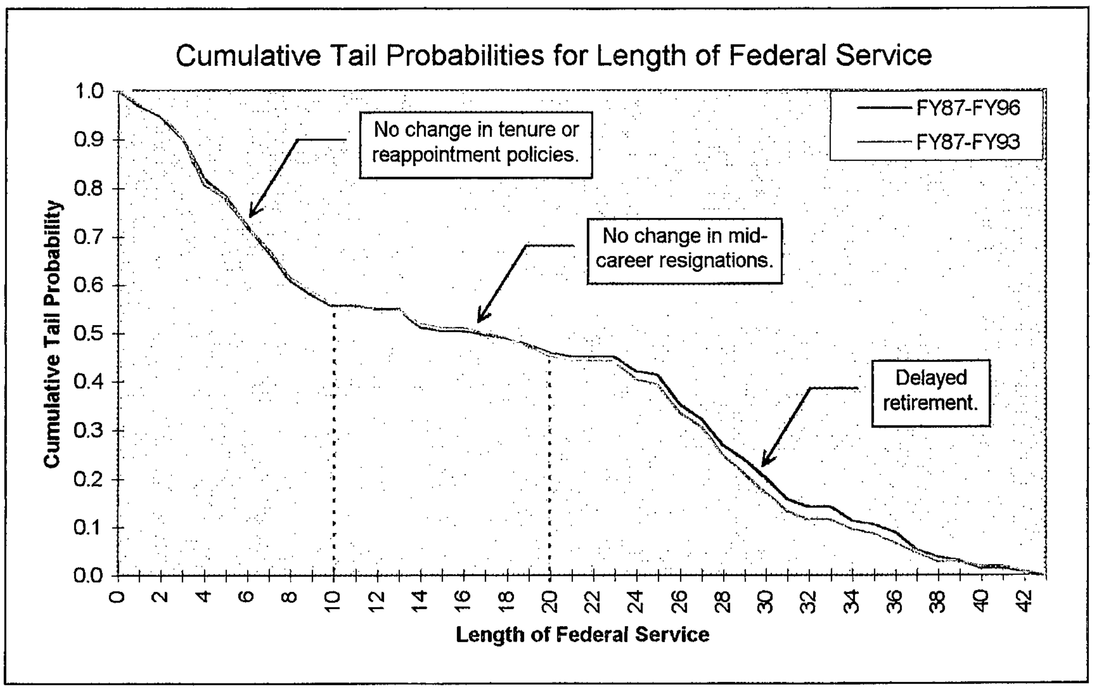

Figure 3.1

Figure 3.2 is a plot of the cumulative tail probabilities for faculty members with LFS ≥ 20. This plot more clearly shows the separation between the two curves. A number of factors could have caused an apparent delay in faculty retirement decisions.

The annuity paid to a federal retiree depends on the LFS of the individual at retirement and on the salary level averaged over the three years of highest pay. In 1989 the maximum 12-month faculty salary level was $75,500. By October 1991 this had risen to $100,500 and by January 1994 to $110,616. In addition to this unusual rise in maximum salary level following a decade of modest growth, NPS was granted permission and resources to award competitive pay raises to faculty in specific disciplines based on the fact that federal salaries had lagged behind those paid in civilian institutions. Thus in addition to increases in the pay cap, additional pay steps were added to the professor scale in June 1991 and to the associate professor scale in 1992. Based on these facts it is not surprising that the loss data plotted in Figures 3.1 and 3.2 show a lower loss rate in the retirement eligible section of the loss curves (LFS > 20) when losses from FY94-FY96 are added to those from FY87-FY93.

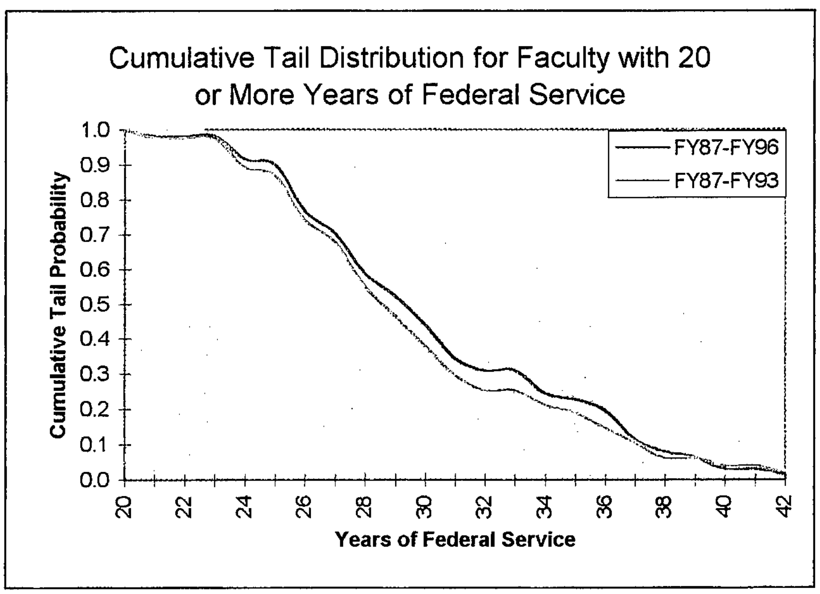

Figure 3.2

C. FACULTY LEGACY FORECASTS

A cross section of NPS faculty at the end of FY93 is shown in Figure 3.3. By convention we say that $t = 0$ at the end of FY93. Therefore, each faculty member i has LFS equal to l_i at the end of FY93.

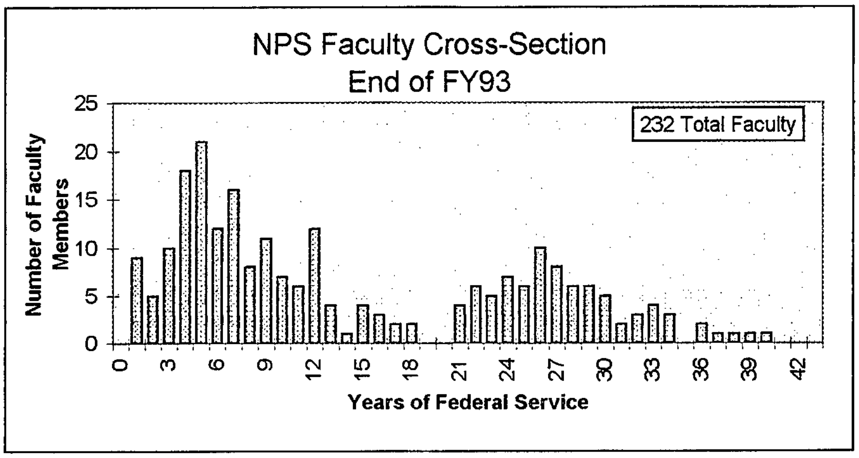

Figure 3.3

Table 3.1 contains the model structure and legacy forecasts. An additional step has been added to the original model for space considerations and ease of use. Rather than trace all 232 legacies individually we combine faculty members by their length of federal service, l_i. We do this in the second column, where $I_0(x)$ is the number of faculty members present at $t = 0$ with x years of federal service. The result of this modification is that we now have a series of *Binomial* (n,p) *trials*, where $I_0(x)$ and $c(x)$ correspond to n and p respectively. Using this intermediate step, the expected number of faculty members with x years of federal service in each successive fiscal year t is

$$E[I_t(x)] = I_0(x-t)\prod_{j=1}^{t} c(x-j), \tag{10}$$

and the variance is

$$Var[I_t(x)] = I_0(x-t)\left[\prod_{j=1}^{t} c(x-j)\right]\left[1-\prod_{j=1}^{t} c(x-j)\right]. \tag{11}$$

To demonstrate, let us predict the legacies for faculty members with seven years of federal service in FY93. From Table 3.1, $I_0(7) = 16$ and $c(7) = .9333$, therefore the expected number of these faculty members still present at the end of FY94 (now with eight years of federal service) is (16)(.9333) = 14.933 with a variance of (16)(.9333)(.0667) = .9956. Similarly, the expected number of these faculty members still present at the end of FY95 is (16)(.9333)(.9143) = 13.6533 with variance (16)(.9333)(.9143)(1-[.9333][.9143]) = 2.0025.

By summing Equations (10) and (11) over all x for each year t, we achieve the same expressions for $E[N(t)]$ and $Var[N(t)]$ as shown in Equations (7) and (8); these sum totals appear at the bottom of each respective column in Table 3.1.

It is here we note a particular result of the model's structure. Because $E[N(t)]$ and $Var[N(t)]$ are calculated by summing the expectations of a sufficient number of Binomial random variables (40), we can say that $N(t)$ is distributed *normally* with mean $E[N(t)]$ and variance $Var[N(t)]$ due to the Central Limit Theorem [DeVore, 1991]. This result allows a user to readily calculate confidence intervals on the projected number of faculty legacies.

Table 3.2 contrasts the legacy forecasts with the actual legacies. The model tends to underestimate the number of legacies, i.e. overestimate the number of losses; both the FY94 and FY95 forecasts fall just inside the upper 95% confidence interval around the mean, which is consistent with the observations in Figure 3.1.

	END FY93		FY1994		FY1995		FY1996	
x	$I_0(x)$	$c(x)$	$E[I_1(x)]$	$Var[I_1(x)]$	$E[I_2(x)]$	$Var[I_2(x)]$	$E[I_3(x)]$	$Var[I_3(x)]$
0	0	1.0	**0.0000**		**0.0000**		**0.0000**	
1	9	0.9712	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2	5	0.9802	8.7404	0.2521	0.0000	0.0000	0.0000	0.0000
3	10	0.9495	4.9010	0.0970	8.5673	0.4119	0.0000	0.0000
4	18	0.8936	9.4949	0.4795	4.6535	0.3225	8.1346	0.7822
5	21	0.9643	16.0851	1.7112	8.4848	1.2856	4.1584	0.6999
6	12	0.9259	20.2500	0.7232	15.5106	2.1451	8.1818	1.4876
7	16	0.9333	11.1111	0.8230	18.7500	2.0089	14.3617	2.9029
8	8	0.9143	14.9333	0.9956	10.3704	1.4083	17.5000	2.9167
9	11	0.9531	7.3143	0.6269	13.6533	2.0025	9.4815	1.9899
10	7	0.9508	10.4844	0.4915	6.9714	0.8963	13.0133	2.4292
11	6	1.0000	6.6557	0.3273	9.9688	0.9346	6.6286	1.1363
12	12	0.9828	6.0000	0.0000	6.6557	0.3273	9.9688	0.9346
13	4	1.0000	11.7931	0.2033	5.8966	0.1017	6.5410	0.4289
14	1	0.9474	4.0000	0.0000	11.7931	0.2033	5.8966	0.1017
15	4	0.9815	0.9474	0.0499	3.7895	0.1994	11.1724	0.7705
16	3	1.0000	3.9259	0.0727	0.9298	0.0653	3.7193	0.2610
17	2	0.9811	3.0000	0.0000	3.9259	0.0727	0.9298	0.0653
18	2	0.9808	1.9623	0.0370	2.9434	0.0555	3.8519	0.1427
19	0	0.9608	1.9615	0.0377	1.9245	0.0726	2.8868	0.1089
20	0	0.9592	0.0000	0.0000	1.8846	0.1087	1.8491	0.1396
21	4	0.9787	0.0000	0.0000	0.0000	0.0000	1.8077	0.1738
22	6	1.0000	3.9149	0.0833	0.0000	0.0000	0.0000	0.0000
23	5	1.0000	6.0000	0.0000	3.9149	0.0833	0.0000	0.0000
24	7	0.9130	5.0000	0.0000	6.0000	0.0000	3.9149	0.0833
25	6	0.9762	6.3913	0.5558	4.5652	0.3970	5.4783	0.4764
26	10	0.8537	5.8571	0.1395	6.2391	0.6782	4.4565	0.4844
27	8	0.9143	8.5366	1.2493	5.0000	0.8333	5.3261	1.2736
28	6	0.8125	7.3143	0.6269	7.8049	1.7133	4.5714	1.0884
29	6	0.8462	4.8750	0.9141	5.9429	1.5282	6.3415	2.3200
30	5	0.8182	5.0769	0.7811	4.1250	1.2891	5.0286	1.8678
31	2	0.7778	4.0909	0.7438	4.1538	1.2781	3.3750	1.4766
32	3	0.8571	1.5556	0.3457	3.1818	1.1570	3.2308	1.4911
33	4	1.0000	2.5714	0.3673	1.3333	0.4444	2.7273	1.2397
34	3	0.8333	4.0000	0.0000	2.5714	0.3673	1.3333	0.4444
35	0	0.9000	2.5000	0.4167	3.3333	0.5556	2.1429	0.6122
36	2	0.7778	0.0000	0.0000	2.2500	0.5625	3.0000	0.7500
37	1	0.7143	1.5556	0.3457	0.0000	0.0000	1.7500	0.7292
38	1	0.6000	0.7143	0.2041	1.1111	0.4938	0.0000	0.0000
39	1	1.0000	0.6000	0.2400	0.4286	0.2449	0.6667	0.4444
40	1	0.6667	1.0000	0.0000	0.6000	0.2400	0.4286	0.2449
41	0	1.0000	0.6667	0.2222	0.6667	0.2222	0.4000	0.1333
42	0	0.5000	0.0000	0.0000	0.6667	0.2222	0.6667	0.2222
43	0	0.0000	0.0000	0.0000	0.0000	0.0000	0.3333	0.2222
	232		215.8	14.16	200.6	24.93	185.3	33.08

Table 3.1. Faculty forecasts for fiscal years 1994 through 1996.

The earlier comments regarding faculty pay levels and their possible effects on delayed retirement appear to be verified by the forecast legacies listed in Table 3.2. It is to

be expected that future changes in the pay levels, or changes in the retirement system rules, such as the recent Congressional proposal to base annuities on the average of five years instead of three years, if enacted, will also change continuation rates. However, this increase in the number of years used to calculate average high pay is unlikely to occur and salaries are not expected to rise more quickly than the annual cost of living increase. Thus, since there are no foreseeable incentives to remain in service longer than an individual's planned retirement age, it is likely that continuation rates for LFS greater than 20 years will decrease in the next five years to those shown in Figure 3.1 for the FY87-FY93 data.

	FY94	**FY95**	**FY96**
Observed legacies	223	210	203
Forecast	215.8	200.6	185.3
95% C.I.	$\pm$ 7.4	$\pm$ 9.8	$\pm$ 11.3
Within C.I.	Yes	Yes	No

Table 3.2. Comparison of legacy forecasts to observed legacies.

D. HIRING POLICIES

Although faculty loss tendencies appear to have been influenced by recent changes in retirement policies, the overall average time spent in federal service, L_i, seems to remain reasonably constant, increasing from 17.8 years to 18.1 years when the loss data from FY94-FY96 were included. We demonstrate Equation (9) in Table 3.3, where the number of recruits per year, λ, necessary to maintain a desired faculty level, N is calculated for both values of $E[L_i]$. The value of λ that corresponds to each N does not differ significantly between the two values of $E[L_i]$. It is interesting to note that a faculty level

range of 10-15 person can be maintained by varying the number of recruits by a single person.

N	$\lambda_{E[Li]=17.8}$	$\lambda_{E[Li]=18.1}$
175	9.8	9.6
180	10.1	9.9
185	10.4	10.2
190	10.6	10.5
195	10.9	10.8
200	11.2	11.0
205	11.5	11.3
210	11.8	11.6
215	12.0	11.9
220	12.3	12.1
225	12.6	12.4
230	12.9	12.7
235	13.2	13.0

Table 3.3. Faculty recruits necessary to maintain steady-state faculty levels.

IV. FORECASTING RETIREMENTS

In this chapter we develop a model to forecast faculty retirements based upon two elements, Age and LFS. The original model is first modified to accommodate the additional element, then sample data are used to test the model as in Chapter III.

A. METHODOLOGY

Up to this point we have developed a model that is intended to predict all faculty losses, regardless of their cause. The continuation rates at the heart of the model have been based upon one of the three elements of loss data, YNPS, LFS and Age. However, if we focus our attention on only retirements, it is believed that a more accurate model can be developed if a combination of elements are incorporated into the forecast, specifically Age and LFS. Recall that retirement eligibility is based upon an individual's age and length of federal service. Table 4.1 is the matrix of age and federal service requirements for retirement eligibility under the Civil Service Retirement System (CSRS). If a faculty member does not have the minimum number of both LFS and Age, then the probability of retirement (with the exception of disability retirement) is zero. It is therefore implicitly assumed that we shall deal only with retirement eligible faculty for the remainder of this chapter.

Age	Length of Federal Service
55-59	30
60-62	20
>62	5

Table 4.1. CSRS retirement eligibility matrix.

B. MODEL DEVELOPMENT

Let A_i and L_i be the random variables for a faculty member's age and LFS, respectively. Additionally, we define an indicator variable R_i where

$$R_i = \begin{cases} 1 & \text{if faculty member } i \text{ retires,} \\ 0 & \text{otherwise.} \end{cases}$$

Thus, the probability that faculty member i retires is $E[R_i]$.

Our goal is to determine the probability that a faculty member i will retire, given that i has age equal to a and LFS equal to l. That is, $P\{R_i=1 \mid A_i=a, L_i=l\}$. To do this, we employ Bayes' rule, such that

$$P\{R_i = 1 | A_i = a, L_i = l\} = \frac{P\{A_i = a, L_i = l | R = 1\} P\{R_i = 1\}}{P\{A_i = i, L_i = l\}}. \tag{12}$$

We can estimate the conditional distribution in the numerator of Equation (12) by using retirement data. A total of 40 retirements occurred between FY87 and FY93. With so few data points it is not feasible to create a probability matrix for every combination of Age and LFS. Therefore, five-year wide bins are used to arrange the data. Table 4.2 lists the loss data by this method.

		Years of Federal Service					
		<20	20-25	25-30	30-35	≥35	
Age	55-60	0	0	2	4	1	7
	60-65	0	2	10	1	1	14
	65-70	1	2	6	1	5	15
	≥70	0	0	0	1	3	4
		1	4	18	7	10	40

Table 4.2. Faculty retirements FY87-FY93.

Once the data are in this form we get an estimate of $P\{A=a, L=l \mid R=1\}$ by dividing each entry by the total number of retirements, shown in Table 4.3.

		Years of Federal Service				
		<20	20-25	25-30	30-35	≥35
Age	55-60	0	0	0.050	0.100	0.025
	60-65	0.000	0.050	0.250	0.025	0.025
	65-70	0.025	0.050	0.150	0.025	0.125
	≥70	0	0	0	0.025	0.075

Table 4.3. Joint conditional distribution of faculty retirements.

The denominator, $P\{A=a, L=l\}$, is estimated by taking the cross sectional faculty profile at the end of each fiscal year and listing retirement eligible faculty members according to the Age and LFS categories they will be in during the following fiscal year. This procedure is analogous to the one performed above on the loss data. A total of 43 faculty members were retirement eligible during FY94, and their Age-LFS distribution is listed in Table 4.4.

		Years of Federal Service				
		<20	20-25	25-30	30-35	≥35
Age	55-60	0	0	0	0.0930	0
	60-65	0.0698	0.0698	0.0930	0.2093	0.0465
	65-70	0.0465	0.0233	0.0930	0.0697	0.0233
	≥70	0.0233	0	0.0698	0.0233	0.0465

Table 4.4. Faculty Age-LFS distribution during FY94.

The final piece of the model is the *prior*, $P\{R=1\}$, i.e. the percentage of retirement eligible faculty who actually retire in a given year. The prior can be estimated in many different ways, such as a one-year point estimate or an historic average over several years. For demonstration purposes, this thesis uses retirement percentage from the previous year,

FY94, where five retirements occurred out of 43 eligible faculty members for a 11.63% retirement rate, or $P\{R=1\} = 0.1136$.

C. FORECAST EXAMPLE

To test the retirement forecast model, we predict the expected number of retirements for FY95. First, we divide each element (a, l) for $P\{A=a,L=l \mid R=1\}$ by the corresponding element of $P\{A=a,L=l\}$ from Tables 4.3 and 4.4. The next step is to multiply the subsequent 4×5 matrix by $P\{R=1\}$. Each cell of the resulting matrix is the expected number of retirements for that specific combination of Age and LFS. By summing over all (a, l) we get the total expected retirements. Table 4.5 shows the final forecast matrix. A total of nine faculty retirements occurred in FY95; The model's prediction of ≈5 retirements is well short of this number. A similar forecast for FY96 also predicted ≈5 retirements, while only two retirements occurred that year.

		Years of Federal Service				
		<20	20-25	25-30	30-35	≥35
Age	55-60	0	0	0	0.375	0
	60-65	0	0.0833	1.563	0.125	0.188
	65-70	0.25	0	0.75	0.208	1.25
	≥70	0	0	0	0.125	0
						Total: 4.92

Table 4.5. Expected number of FY95 faculty retirements.

Some obvious shortcomings in the model may explain at least some of the error. First, the small number of retirement observations (40 from FY87-FY93) is not enough to calculate $P\{A=a,L=l \mid R=1\}$ with any degree of certainty. From Table 4.2 we see that only four of the 20 cells in the matrix have three or more observations, and many have

only one or none at all. However, to collect more retirement observations more years of loss data must be used. This in turn would tend to desensitize the model by masking fluctuations in retirement trends. While the two-element approach to retirement forecasting seems intuitively appropriate, it does not appear that the applied model will yield more accurate or useful forecasts than those obtained by using LFS alone in the model described in Chapter II.

V. CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS

The legacy forecast model can be used to predict effectively future faculty levels as well as develop policies to achieve and maintain a desired faculty base. Decision makers can regulate the model's sensitivity to retention trends by basing the continuation rates on only a few years of loss data, or they can smooth the loss function by including more years of loss data. The spreadsheet-based model is easy to use and gives decision makers a flexible, adaptable tool to base tenure and hiring practices.

B. LIMITATIONS

The model's assumption of independent faculty losses can be violated. For instance, if a faculty member's spouse is also a faculty member, the event that one of them leaves would seem to have a major effect on the other's retention characteristics. Additionally, the model assumes independent and identical loss distribution (IID) throughout NPS. Specific retention characteristics of each department were not investigated, and could very well differ from curriculum to curriculum. For example, if there is a greater demand in the civilian sector for certain academic disciplines, the retention characteristics of their associated departments could differ greatly from others.

C. FUTURE RESEARCH

A complete decision aid for basing hiring and tenure policies will require additional work. The initial legacy forecast model presented here appears to have captured the

delayed retirement trend as discussed in Chapter III, but additional loss data is needed to better validate the results. Specific loss characteristics for each academic department should be analyzed to assess the validity of the IID loss assumption.

In its present form, the faculty legacy forecast model is keystroke intensive. A graphical user interface, perhaps integrated into a database such as Microsoft Access or Corel InfoCentral should be developed to streamline the generation of forecasts and faculty profiles.

APPENDIX A. FACULTY LOSS DATA

Age at Loss	
Years	Losses
29	0
30	2
31	2
32	1
33	2
34	0
35	5
36	6
37	5
38	3
39	6
40	2
41	6
42	3
43	3
44	4
45	3
46	1
47	0
48	4
49	4
50	3
51	1
52	2
53	0
54	2
55	0
56	5
57	1
58	2
59	3
60	2
61	10
62	4
63	3
64	4
65	2
66	4
67	5
68	4
69	6
70	1
71	1
72	5
73	1
	133

Length of Federal Service at Loss	
Years	Losses
0	0
1	4
2	3
3	6
4	11
5	5
6	8
7	7
8	8
9	4
10	3
11	0
12	1
13	0
14	5
15	1
16	0
17	1
18	1
19	2
20	2
21	1
22	0
23	0
24	4
25	1
26	8
27	4
28	7
29	4
30	5
31	6
32	2
33	0
34	4
35	1
36	2
37	5
38	2
39	1
40	2
41	0
42	1
43	1
	133

Length of NPS Service at Loss	
Years	Losses
0	0
1	4
2	6
3	9
4	11
5	7
6	10
7	9
8	8
9	3
10	0
11	0
12	1
13	0
14	2
15	0
16	1
17	0
18	2
19	1
20	2
21	4
22	2
23	1
24	4
25	3
26	5
27	4
28	5
29	5
30	6
31	4
32	1
33	0
34	1
35	2
36	2
37	3
38	2
39	1
40	0
41	0
42	1
43	1
	133

Table A.1. Faculty loss statistics, FY87-FY96.

APPENDIX B. DATA DISTRIBUTION AND CALCULATIONS

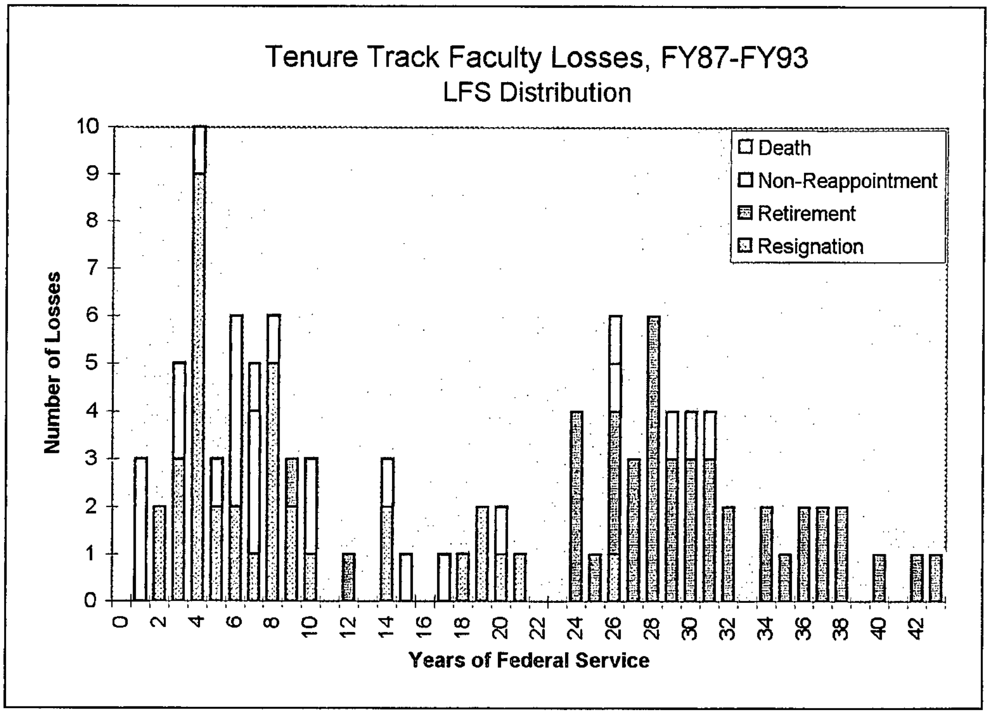

Figure B.1

x	#LFS=x	P{LFS=x}	P{LFS>x}	$c(x)$
0	0	0	1	1
1	3	0.0288	0.9712	0.9712
2	2	0.0192	0.9519	0.9802
3	5	0.0481	0.9038	0.9495
4	10	0.0962	0.8077	0.8936
5	3	0.0288	0.7788	0.9643
6	6	0.0577	0.7212	0.9259
7	5	0.0481	0.6731	0.9333
8	6	0.0577	0.6154	0.9143
9	3	0.0288	0.5865	0.9531
10	3	0.0288	0.5577	0.9508
11	0	0.0000	0.5577	1.0000
12	1	0.0096	0.5481	0.9828
13	0	0.0000	0.5481	1.0000
14	3	0.0288	0.5192	0.9474
15	1	0.0096	0.5096	0.9815
16	0	0.0000	0.5096	1.0000
17	1	0.0096	0.5000	0.9811
18	1	0.0096	0.4904	0.9808
19	2	0.0192	0.4712	0.9608
20	2	0.0192	0.4519	0.9592
21	1	0.0096	0.4423	0.9787
22	0	0.0000	0.4423	1.0000
23	0	0.0000	0.4423	1.0000
24	4	0.0385	0.4038	0.9130
25	1	0.0096	0.3942	0.9762
26	6	0.0577	0.3365	0.8537
27	3	0.0288	0.3077	0.9143
28	6	0.0577	0.2500	0.8125
29	4	0.0385	0.2115	0.8462
30	4	0.0385	0.1731	0.8182
31	4	0.0385	0.1346	0.7778
32	2	0.0192	0.1154	0.8571
33	0	0.0000	0.1154	1.0000
34	2	0.0192	0.0962	0.8333
35	1	0.0096	0.0865	0.9000
36	2	0.0192	0.0673	0.7778
37	2	0.0192	0.0481	0.7143
38	2	0.0192	0.0288	0.6000
39	0	0.0000	0.0288	1.0000
40	1	0.0096	0.0192	0.6667
41	0	0.0000	0.0192	1.0000
42	1	0.0096	0.0096	0.5000
43	1	0.0096	0.0000	0.0000
TOTAL	104	1.0	17.846	

Table B.2. Continuation rate calculations for the test data.

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